Eskişehir Osmangazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi Cilt : XXIV, Sayı : 2, 2011
Journal of Engineering and Architecture Faculty of Eskişehir Osmangazi University, Vol : XXIV, No: 2, 2011

Makalenin Geliş Tarihi : 11.09.2011
Makalenin Kabul Tarihi : 25.10.2011

USING MEERSCHAUM IN CONCRETE

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ABSTRACT : *Meerschaum is white claylike mineral of hydrous magnesium silicate. It has an irregular and white colored crystalline structure. It is wet and moisturized under soil and so it is in an easy-to-process after extraction. Wastes are stored in a dry environment and kept ready-to-use form. While processing meerschaum %15-40 of its amount becomes waste. In this study meerschaum waste is used as aggregate in concrete, and the stress-strain diagrams for these concrete specimens are obtained. Also stress-strain diagrams of these concrete specimens are examined. It is concluded that meerschaum waste can be used as aggregate in concrete.*

KEYWORDS : *Meerschaum, Sepiolite, Stress-Strain Diagram, Light Weight Concrete.*

BETON İÇERİSİNDE LÜLETAŞI KULLANIMI

ÖZET : *Lületaşı, magnezyum silikat formda beyaz, kile benzer bir mineraldir. Düzensiz kristalli bir yapıya ve beyaz renge sahiptir. Yeraltında nemli, ıslak olarak bulunur. Bu nedenle çıkarıldığında işlenmesi kolaydır. İşlendiğinde %15-40 atık ortaya çıkar. Atıklar kapalı ve kuru ortamlarda bekletilerek kullanıma hazır tutulur. Bu çalışmada agrega olarak lületaşı atıkları kullanılarak elde edilen betonların gerilme-şekil değiştirme eğrileri elde edilmiş ve incelenmiştir. Çalışma sonucunda lületaşı atıklarının agrega olarak kullanılabileceği görülmüştür.*

ANAHTAR KELİMELER : *Lületaşı, Sepiolit, Gerilme-Şekil Değiştirme, Hafif Beton.*

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I. INTRODUCTION

In German, meerschaum which means “sea froth”, on the old Uighur Turkish called as “Tolay köpüğü”, on the Ottoman Turkish named as “Derya köpüğü”, nowadays Turkish “Lületaşı” ,and scientifically known as sepiolite is represented by the formula $Si_{12}Mg_8O_{30}(OH)_4(H_2O)_4(8H_2O)$ is a natural clay mineral which consists of hydrous magnesium silicate [1]. Structurally, it is formed by alternation of blocks and tunnels which grow up in the fiber direction. Each structural block is composed of two tetrahedral silica sheets sandwiching a central sheet of magnesium oxide-hydroxide [2]. It can be found in two different forms in the nature. One of them is known as α-sepiolite which is amorphous, in compact state, and in the form of pellets which looks like see froth known as by its Turkish name “Lületaşı”. The other one is β-sepiolite which can be found in the form of amorphous aggregate or small flat and round particles [3]. These two forms differ from each other according to the physical properties (Table 1).

Table 1. *Chemical composition of sepiolite*

Kinds of meerschaum		S_iO_2	MgO	AI_2O_3	Na_2O	K_2O	Fe_2O_3	MnO	TiO_2	CaO	Waste losses
α-sepiolite	Meerschaum [4]	52.90	25.89	0.27	---	---	0.36	---	---	0.01	20.55
	Meerschaum [5]	53.02	23.13	0.19	0.02	0.02	0.51	---	---	0.06	21.63
β-sepiolite	Sedimenter sepiolite [6]	55.97	22.81	1.56	0.12	0.27	0.77	0.02	0.12	0.57	17.75
	Sedimenter sepiolite [7]	60.60	22.45	1.73	0.16	0.58	0.62	---	---	0.40	13.22

α-sepiolite is formed when magnesium silicate stone pieces between metamorphosis layers gain water by the hydro-thermal effect [1]. α-sepiolite consists of a fibrous structure. Its length varies between 4-5 microns, and its thickness is about 0.2 microns which is usually found in potato-shaped form. The richest deposits of meerschaum are around Eskisehir, which is a city in the mid-Turkey, and there are some deposits in Konya-Yunak as well. Its unit weight is about 0.508 gr/cm^3. Another important sepiolite class is "sedimentary sepiolite" which was also called as β-sepiolite, "industrial sepiolite" or "layered sepiolite" and unit volume weight is 0.894 gr/cm^3 [8]. β-sepiolite is the one with less fibrous appearance and in shape of scales and with a thickness of 0.5-1 micron. There are many sepiolite types defined in the world and in Turkey in various shapes. Some of them are Fe-sepiolite, Xilotile, Ni-sepiolite, Mn-sepiolite, Al-sepiolite and, Al, Fe-sepiolite which is hydrothermal alteration product of volcano sedimentary materials

(Bolu-Kıbrıscık, Çankırı-Orta). It may be available in the form of pieces varying from 250 gr to 5-7 kg (Figure 1).

***Figure 1**. Different size of meerschaum [9].*

Meerschaums were also studied by Brauner and Preisinger in 1958 [10]. Both of them agree that meerschaum consists of mainly sepiolite ($2MgO•3SiO_2•nH_2O$). According to the researchers, mineral, zeolitic, crystal and structure contain the water. It is used as adsorption means for many liquids, ion changer and used in dispersion and insulation of paraffin in chemical industry. It is mostly used in the area of manufacturing of pipe and ornament goods.

Meerschaum has a very ancient history. As a result of archaeological researches, during the excavations carried out in Demirci Höyük in which a work art made up of meerschaum dated with the BC 3000's was found. Meerschaum has been known and processed for about 5000 years but for whatever it is used and for what reason its has been used in not well known. The ancient art work is still preserved in Eskisehir Archaeology Museum (Figure 2). In some records it is claimed that meerschaum was discovered by a Hungarian traveler between the 1600 and 1700 years. A road from Eskisehir to Vienna allowed meerschaum transport for 300 years. The part of this road which was between Eskisehir and Iznik was called as "Meerschaum Road" by A. Reinhardt [11].

***Figure 2**. Meerschaum [10].*

Meerschaum type sepiolite deposits are present mainly in Turkey, Somali, Tanzania, Kenya and Mexico. Sedimentary sepiolite formations are also present in addition to meerschaum with good quality, low density and high porosity in Somali. Their total reserves are estimated to be about 50-100 million tones.

In the study, compressive strength of concrete specimens with and without meerschaum waste after 7 and 28 days curing time are noted and stress-strain curves ($_{c}$- $_{c}$) of these concrete specimens are obtained according to Eurocode 2 (EC2) and modified Kent-Park correlations. Meerschaum powder, chip and other crude aggregate are used as aggregate. Samples are analyzed by producing 10 units for every mixture and median values are taken. It is found that meerschaum waste may be used in different fields.

II. PRODUCTION METHOD OF MEERSCHAUM

Meerschaum production has been carried out through generally primitive methods for 200 years. In the oldest method whereby the levels containing meerschaum were visited down with a unsupported well and narrow galleries were followed, work is carried out by means of teams consisting of two or three workers (Figure 3.a). This method is called as pulley method. Meerschaum is extracted from 30-100 m. depth, pickaxe, limelight are used as lightening tool and in some regions from 200 m depth by various methods (Figure 3.b). In pulley method, pit diameters vary between 0.60 and 2 m. While moving vertically in the well, small corridors opened on the walls are used. There is no elevator system. Only for allowing gathered nodule meerschaum parts to come up, pulley and buckets or bags of 15-20 litres volume are used (Figure 3.c).

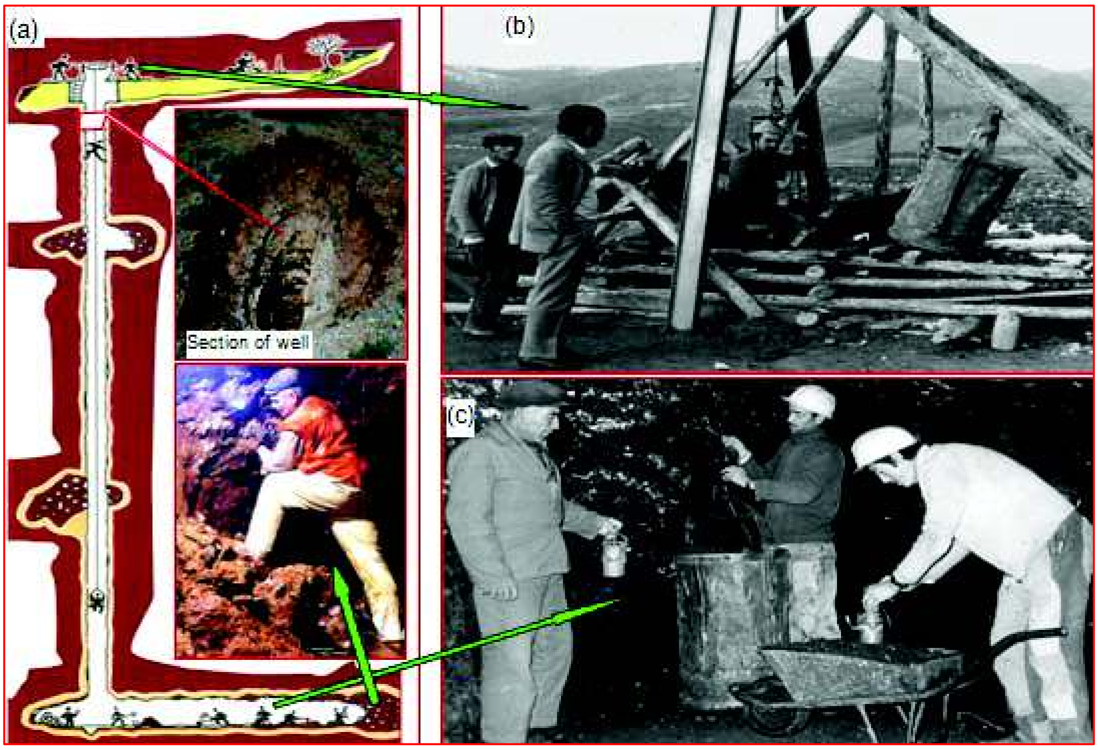

Figure 3. *a) Well length interval b) Well superstructure c) Working on the bottom of well [9].*

Meerschaum reserves are sometimes found in levels below the underground waters. In such case, a serious problem pumping out of the underground water is faced. Since meerschaum mining is still performed through traditional and very primitive methods. Some meerschaum ores could not be accessed yet.

Extracted meerschaum nodules are primarily retained in mines with a humid place by covering with wet sacks and they are prevented from losing structural water. Then, by throwing them into the water, it is ensured that the soil on them is cleaned (Figure 4). Then ones of which soil is taken away are dried and prepared to be processed.

Figure 4. *Phases of Meerschaum extraction and preparation for usage.*

This natural humidity retained by the porous structure of Meerschaum ensures its cleaning while it is in the soil and its easily processing after being extracted. The meerschaum which is dried after either directly or processed gets lighter and it hardens considerably. Physical properties of good Meerschaum are as follows:

1. It is very white,
2. It is very easily chipped,
3. It has no space, foreign body, capillaries within its structure,
4. It gets its original softness when dropped into the water after getting dried,
5. It is not subject to any deformation during wetting and drying and it keeps its volume completely.

Above properties are completely held by meerschaums with nodules. Layered meerschaums diffuse inside the water after getting dried though chipped in its original wetness. The drying cracks don't stay on the surface at all. However, manufacturing of pipe and ornament good out of selected parts is rarely possible. Meerschaum is divided into 7 types as a result of long-year trials by properties such as size, color, pore, lode structure and weight (Table 2). These types are also subdivided into various classes among them.

***Table 2**. Varieties and sizes of meerschaum [12]*

No	Class name	Place of use	Number of pieces in Standard coffer
1	Sorted	Pipe manufacturing	35-40
2	Unit	Trinket and pipe manufacturing	60-70
3	Cotton	Lady pipe manufacturing (the most suitable)	100-150
4	Grained	Lady pipe manufacturing	200-230
5	Medium	Earring, cigarette holder and necklace	300-400
6	Bulk	Prayer beads manufacturing	500-700
7	Thin	Nicotine absorbing lining manufacturing	Very small piece

Varieties except for thin class are also subdivided into additional each 12 varieties among them. Kinds of each type which are from 1 to 7 are good and ones between 7 and 10 are medium and ones between 10 and 12 are low quality. Ornament goods are produced by processing these parts (Figure 5).

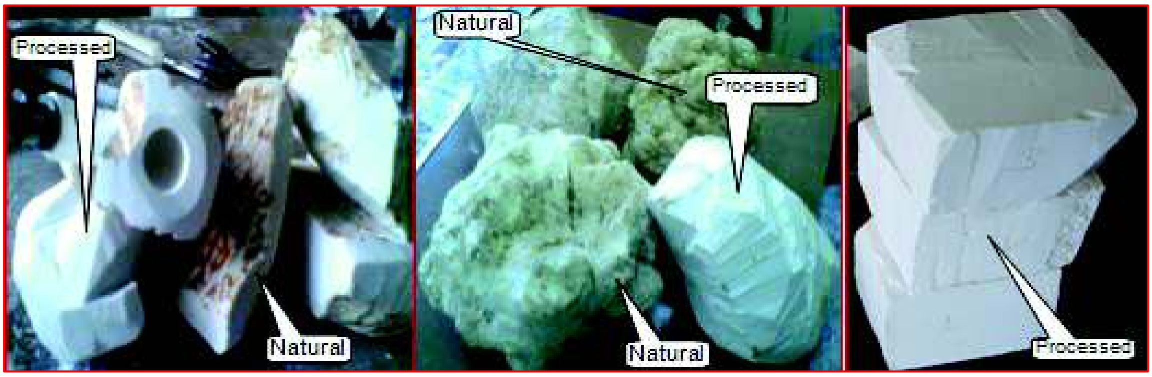

Figure 5. *Phases of extraction and preparation of Meerschaum for use.*

Eskisehir in Turkey has 70 % of world meerschaum reserve (Figure 6). Eskisehir is located between eastern longitude 29-32E and between northern latitude 39-40N (Figure 6) and in an area covering 13.652 square kilometers. Eskisehir consists of thirteen administrative districts. The population of the city is approximately 800,000. Eskisehir's sepiolite mineral may not be compared with any type available in the world in terms of whiteness, lightness and productivity and when you call "pipe stone" that is to say meerschaum, everybody in the world recalls the stone of Eskisehir. Though Meerschaum formations are present in provinces called as Eskisehir and Konya, those with the highest economic importance and which are processed for many years now are extracting in west, northeast and southeast of Eskisehir. Reserve is in a dispersed form. By starting from the depths that are close to the surface and reaching up to the depths of 300 meters, it may be accessed.

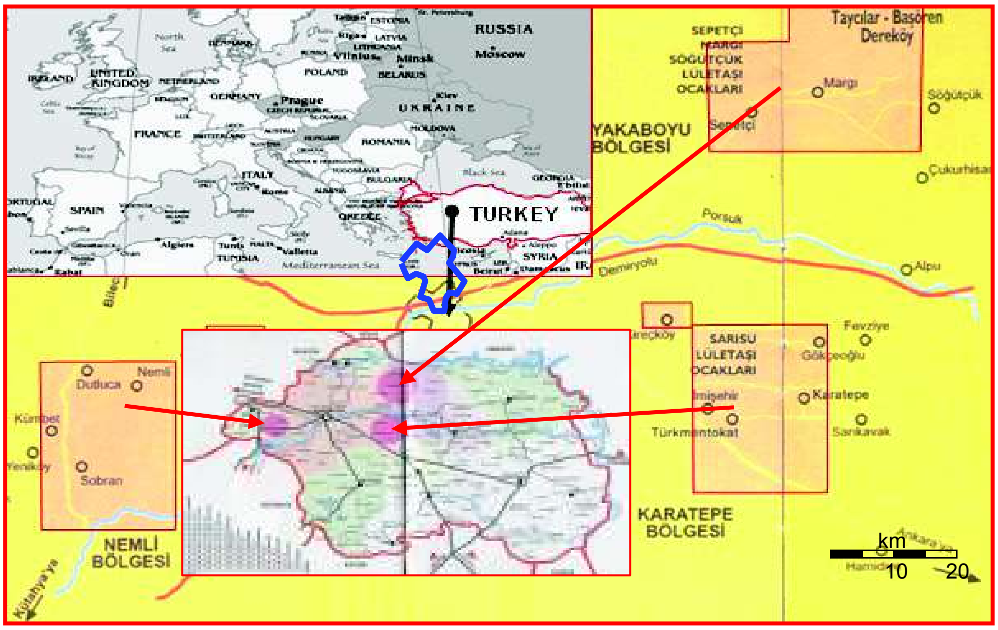

Figure 6. *Meerschaum mines in Eskisehir [8].*

Sepetçi, Margı, Sarısu, Kayı, Gökçeoğlu and Türkmentokat areas on the east of Eskisehir and Nemli-Dutluca areas on west are the most important regions for meerschaum mining. Recently no production is made on western region. Potential reserves of some production areas are stated in Table 3.

Table 3. *Meerschaum reserves of some production areas around Eskisehir [8].*

District	Coffer (1 coffer=12 kg)	Quantity (tonnes)
Sarısu	855,250	10,236
Kayıköyü	853,000	10,200
Gökçeoğlu	460,000	5,520
Total	2,168,250	25,956

Formation of meerschaum is closely related with Eskisehir's underground water system. In Eskisehir, up to the year of 1980, hot water used to flow out of taps present at homes. Still in about 40-50 public baths, natural hot water is used. There are designed projects for the use of such hot water in field of thermal medicine. Many natural assets in Eskisehir have very close relation with such water system. W. E. Petrascheck, a German Researcher, of 1963 mentioned in the unpublished report of 1927 belonging to a researcher named as M. Lucius stated that formation of Eskisehir meerschaum is related with thermal waters and its reserve was 2-3 thousand tones [2].

Among the basic reasons for the fact that Eskisehir meerschaums are of good quality and there are reasons stating that there are rock (solutions) of sedimentation basins which are precipitation of neogen lithology containing sufficient M_gO and S_iO_2 which provides formation of meerschaum. And also the fact that there is 8-8.5 Ph value to enable formation of sepiolite. The fact that sufficient geological conditions are jointly present also increases the sepiolite quality.

III. CONSUMPTION OF MEERSCHAUM

Meerschaum is mainly consumed in manufacturing of pipe and ornament goods. In this area, good quality stones are used, waste and low quality stones are consumed as pipe lining and press material.
Meerschaum and its waste arise during the manufacturing of above stated ornament goods and low quality meerschaums were used as aggregate in cement at various rates. Huge amounts of wastes are produced during the preparation of Meerschaum for use after extraction from mine and due to its veined structure and during its processing. Depending on the good being manufactured and type of meerschaum, a waste which is about 15-40% of meerschaum is produced. Great part of these wastes is chip which is obtained as a result of peeling of meerschaum just like peeling of a potato with a knife (Figure 7.a). Another class consists of parts with a diameter of 10 mm and 40 mm. Another waste is meerschaum powder which is obtained as a result of emery of surfaces of goods made up of meerschaum and their correction on lathes (Figure 7.b,c).

Figure 7. *Chip and dust waste of meerschaum.*

Meerschaum waste is gathered from mines and workshops and stored in a place. These wastes are used for various purposes. Main use areas are as follows; they are laid down in basements of buildings with a thickness of 50-100 mm. In this study as well, it is planned to be used in production of concrete. In dry phase it floats on the water. When it initially gets out of the well and when it absorbs the water, it sinks into the water (Figure 8). Its water absorption rate by weight (24 hours) is approximately about 35-50%.

Figure 8. *Sink tests of meerschaum.*

In order to obtain the carrying power of Meerschaum, each 10 cube samples at the size of 40x40x40 mm and 70x70x70 mm were broken on the press (Figure 9).

Figure 9. *Compression tests of meerschaum.*

Compressive strength of meerschaum as a result of such tests is about 6 kg/cm^2 and samples were dispersed by being vertically and horizontally broken (Figure 10.a). Here it is not possible to find a standard value due to the structure of meerschaum. The fact that samples are dry has great impact on such a resistance. Because meerschaum is not dispersed during its break without being dried and its length gets shorter just like soap and it widens horizontally (Figure 10.b).

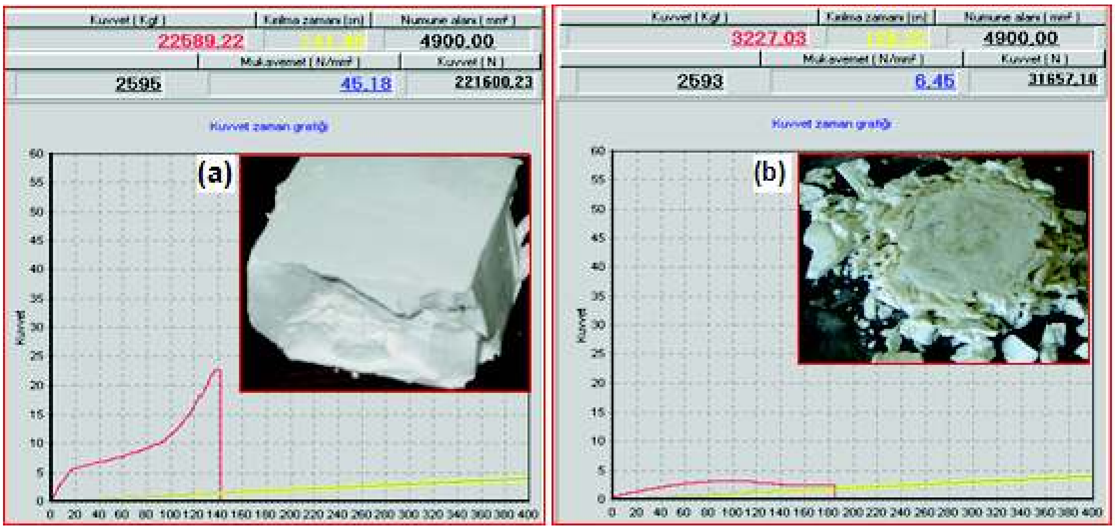

Figure 10. *Meerschaum samples a) dry b) wet (When extracted from the well).*

Huge amount of chips are produced from chipping the meerschaum with hand tools such as knife since it is a soft material. These chips easily become powder after getting dried. Samples produced by using chips were used instead of fine sand (Table 4). Others 10% and 20% are meerschaum rates in fine and coarse aggregates. 100% is the sample where all fine and coarse aggregates are meerschaum. Compressive strength of concrete obtained as a result of use of full of aggregate as meerschaum is reasonably lower than the others. Additionally, in case where full of aggregate is meerschaum, the water rate required to constitute the concrete viscosity in line with feature of meerschaum increases by 1.3-2 rate when compared with other samples. In such a case, it decreases the compressive strength of the concrete. While the meerschaum rate within the concrete gets higher, the amount of required water also gets higher. Concrete samples were broken in presses by being extracted after 7 and 28 days after being put into curing pools following the fact that they are poured into experiment containers (Figure 11).

Figure 11. *Phase of breaking the samples.*

Obtained concrete compressive strength results were given in Table 4.

Table 4. Sample properties and test results.

	Samples meerschaum contribution rates			
	Chip	10%	20%	50-100%
Curing Time	Average compressive strength (N/mm^2)			
7 days	27.40	14.40	9.28	7.16
28 days	35.70	20.70	12.90	9.77
Specific gravity (g/cm^3)	2.38	2.25	1.95	1.45

Since the unit volume weight of these samples is very low, light concrete specimens are can be produced. The unit weight of meerschaum is defined according to the Turkish standard TS3624. In TS3624 the aggregates in the concrete should have an unit weight of 2.00-2.80 kg/dm^3. But the unit weight of meerschaum has been found to be 1.00-0.894 kg/dm^3. As it can be seen from Fig.12a, when the amount of meerschaum used in the specimens increases, the unit weight of the specimens decrease. The rate of water absorption of normal weight concrete is %4.5, the concrete made by using %45 meerschaum waste has an absorption rate of %9.5 (Figure 12.b).

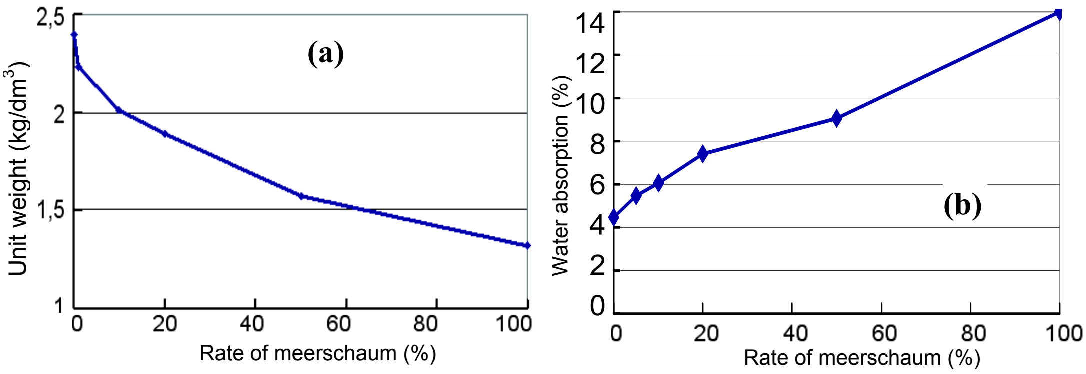

Figure 12. *(a) Unit weight (b) water absorption.*

The concrete specimens made with meerschaum wastes are lighter than the specimens made with concrete (Figure 12.a). The usage of light weight concrete become more popular especially in Belgium, Netherlands, Germany, England and U.S.A and its usage rate is increasing. The classification of the light weight concretes changes from one country to another according to their specifications. For example in TS 2511 the dry unit weight should not exceed 1900 kg/m^3, in ASTM C330-69 the unit weight should be less than 1840 kg/m^3 and the cylinder compressive strength for 28 days cured concrete must be less than 17 MPa. Also in DIN 1045 concrete of which unit weight is less than 2000 kg/m^3 is accepted as the light weight concrete. In this study concrete specimens with meerschaum waste are lighter than the above mentioned values.

IV. UNCONFINED CONCRETE MODEL

Eurocode 2 (EC2) is the European Code for reinforced concrete structures, and is one of the nine codes which contain the rules for designing the reinforced concrete buildings [13]. A comparison of EC2 and modified Kent-Park concrete models are given in Figure 13. The proposed model can be used for calculating the internal forces and deformations in the members. This model is progressed by considering the model proposed by Sargın [14] (Eq.1-2).

$$\sigma_c = f_{co} \left(\frac{k\,\eta^2 - \eta}{1 + (k - 2)\eta} \right) \tag{1}$$

In the above equation E_{cs} and f_{co} should be expressed in terms of N/mm^2 (MPa).

$$\eta = \frac{\varepsilon_c}{\varepsilon_{co}} \qquad _{co} = 0.0022 \qquad k = 1.1\, E_{cs}\ _{co} / f_{co} \qquad E_{cs} = 9500(f_{co}+8)^{1/3} \tag{2}$$

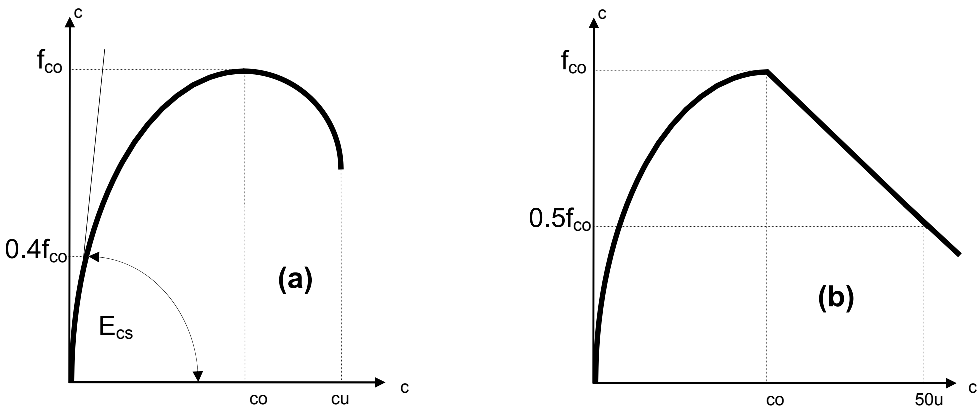

Figure 13. *$_c$ - $_c$ curves for unconfined concrete (a) EC2 [13] (b) Modified Kent-Park [15]*

In modified Kent-Park model, the initial portion until the maximum stress f_{co} is approximated by a second degree curve (Eq. 3). The second portion (descending portion) is assumed to be linear with a strain ε_{50u} which corresponds to $0.5f_{co}$ (Eq. 4). The strain corresponding to f_{co} is denoted as $_{co}$ and it is equal to 0.002.

$$\sigma_c = f_{co}\left[\frac{2\,\varepsilon_c}{\varepsilon_{co}} - \left(\frac{\varepsilon_c}{\varepsilon_{co}}\right)^2\right] \qquad (3)$$

$$\varepsilon_{50u} = \frac{0.3 + 0.0285\,f_{co}}{14.2\,f_{co} - 100} \qquad Z = \frac{0.5}{\varepsilon_{50u} - \varepsilon_{co}} \qquad \sigma_c = f_{co}\left(1 - Z\left(\varepsilon_c - \varepsilon_{co}\right)\right) \qquad (4)$$

In this study, the $_c$ - $_c$ curves for concrete using meerschaum waste (Figure 14.a.b) are drawn with accordance of EC2 and modified Kent-Park curves.

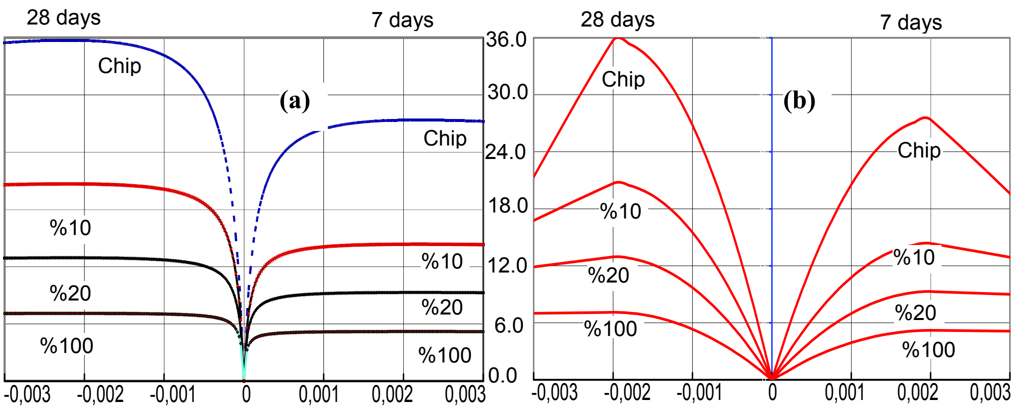

Figure. 14. *$_c$ - $_c$ curves for concrete with meerschaum wastes (a) EC2 (b) Kent-Park.*

As it can be seen from the above curves the compressive strength decreases when the meerschaum rate within the concrete gets higher. The strength of concrete gets even lower; especially in case where meerschaum is used as fine and coarse aggregate. In this case also the amount of required water gets higher and the unit weight decreases (Table 4). Using the meerschaum powder in the concrete samples is not as effective as normal weight aggregate when the compressive strength of concrete is considered.

V. CONCLUSIONS

The unit weight of concrete specimens with meerschaum aggregate is lower than the concrete specimens with normal aggregates. Using only meerschaum as aggregate in concrete makes concrete specimens much more lighter. In some of the towns nearby meerschaum mines it is used as aggregate, but it cannot be used in structural system elements such as columns and beams. However, meerschaum concrete could be more appropriate to be used in leveling surface, hedges, highway barriers and as a filler. Using meerschaum waste as aggregate not only makes concrete lighter but also it provides sound and heat isolation. The environment could also be protected by recycling meerschaum waste. Unless these wastes are utilized, their disposal could be a big problem.

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